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Developing physical capability standards that are predictive of success on Special Forces Selection courses

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ABSTRACT

This study aimed to develop physical capability standards for panelling candidates onto the Special Forces selection courses of the Australian Army. One hundred and four male soldiers undertook nine physical capability assessments (vertical jump, sit and reach, push-ups, seven-stage sit-ups, heaves, agility, 20-m shuttle run, loaded 5-km pack march, and a 400-m swim) before commencing, and attempted two barrier assessments (3.2-km battle run and 20-km march) at the beginning of, the selection course. Several assessments were significantly associated with performance on the barrier assessments and selection course outcome (pass/fail), however the statistical models lacked sufficient sensitivity to ensure zero false negative classifications. Alternatively, manual analysis identified a combination of physical capability standards that correctly classified 14-18% of candidates likely to fail, without excluding any candidates able to pass. The standards were applied and refined through a second cohort of 92 male soldiers on a subsequent selection course, and include completing the 5-km pack march in $\leq 45:45$ min:s, achieving \geq level five or greater on the sit-up test, or completing ≥ 66 push-ups. The implementation of these standards may benefit the Special Forces selection process by reducing attrition rates, lowering the financial and logistical burdens of selection course coordination, and enhancing recruitment opportunities.

INTRODUCTION

The physical demands of military training and selection courses are high and it is important that candidates who commence such courses possess the necessary physical capabilities to reduce their risk of injury and promote their chances of success. Personnel commencing basic training with insufficient physical capability are at greater risk of sustaining an injury [1] and are more likely to be unsuccessful [1-4]. Both of these outcomes carries a logistical and financial burden to the military, and are discouraging for the individual. The physical demands of Special Forces selection courses greatly exceeds those placed on soldiers during basic training, with success on such courses also associated with physical capability in these elite military populations [5].

Soldiers serving in the Australian Army Special Forces are required to maintain a high degree of physical conditioning if they are to perform the arduous physical tasks required of their role. To ensure each soldier has the necessary physical capability, Special Forces candidates must complete a rigorous four-week selection course. Over the past six years, the pass rates for the Australian Army Special Forces selection courses span a wide range from 18-70%. These data show that a high proportion of candidates who commence Special Forces selection courses are unsuccessful. One of the reasons for these low completion rates may include an insufficient physical capability of the candidates. To mitigate the likelihood of unsuccessful course completion or sustaining an injury, potential candidates for Special Forces selection courses in the Australian Army are required to undertake a battery of physical capability assessments known as the Special Forces Entry Test (SFET).

The SFET includes a series of nine assessments of physical capability components such as muscular strength and endurance, as well as aerobic and anaerobic power. However, the sensitivity and specificity of these general fitness assessments to predict selection course outcomes have not been investigated. For the SFET to effectively evaluate a candidate's physical readiness to commence the selection course, it is imperative that minimum performance standards for SFET assessments possess a high sensitivity. This would eliminate the potential for a candidate who is capable of successfully completing the selection course being removed from the course panel, and consequently the loss of a valuable Special Forces operator. Similarly, a high degree of specificity in the SFET assessments would reduce the number of candidates commencing the selection course who are likely to be unsuccessful. This in turn would lower the attrition rate and reduce the risk of injury, as well as lowering the financial and logistical burden of conducting the selection courses.

In the first few days of the selection courses, candidates must complete a 20-km march and a 3.2-km battle run. These are known as barrier assessments because candidates are removed from the course if they fail to meet the completion time requirement. Since these assessments are performed at the outset of the selection course, candidates commencing the course are expected to be at a level of physical capability enabling them to pass these particular assessments. On this basis, the association between SFET assessments and barrier assessment performance should also be evaluated.

This study was conducted in two parts. Part A of this study aimed to determine if physical capability assessments from the SFET could: 1) reliably predict performance on the barrier assessments at the beginning of the selection course; and 2) distinguish the barrier assessment and selection course outcomes (Pass/Fail). Part B of the study involved the application of the SFET standards developed in part A to predict selection course outcomes with a different cohort of candidates.

METHODS

Participants from all Australian service arms and units self-selected to attend the SFET with the express goal of performing to a standard deemed suitable for acceptance onto either the Commando Selection and Training Course (CSTC) or Special Air Services Selection Course (SAS-SC). One hundred and four (n=104) male candidates with a maximal aerobic power of $54.5 \pm 3.1 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ (estimated from the 20-m shuttle run test [6]) participated in part A of the study. Other descriptive data was only available for 47 of the candidates; showing a mean age of 26.0 ± 3.4 years, height of 180.6 ± 5.5 cm, and body mass of 82.3 ± 7.1 kg. . All candidates completed the SFET and commenced the CSTC, which were separated by a period of up to two months. For part B, 92 out of 97 SFET results for male candidates who commenced the SAS-SC were available; five candidates were excluded from the analysis due to the assessments being conducted outside the regular data capture period. Candidates in part B were 27.6 ± 3.4 years of age, 182.5 ± 6.7 cm tall, weighed 85.40 ± 9.1 kg, and had a maximal aerobic power of $54.4 \pm 3.1 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ [6]. In both parts A and B, physical assessment data from the SFET, the selection course barrier assessments, and selection course outcome (pass/fail) were provided retrospectively for analysis. This

study received ethical approval from the Australian Defence Human Research Ethics committee.

Procedures

The SFET included nine physical capability assessments performed on a single day. The assessments were completed in the following order and included, vertical jump test, sit-and-reach flexibility test, maximum number of push-ups, maximum number of heaves, seven-stage sit-up test, agility test, 20-m shuttle run test, a 5-km pack march, and a 400-m swim.

For the vertical jump assessment, the candidates stood with feet flat on the ground and dominant hand raised vertically to record their standing reach height. Candidates then performed a counter-movement jump and raised their dominant hand as high as possible, marking the highest point reached [7]. Candidates completed three attempts and their best performance was recorded. The sit-and-reach test of flexibility [8] required candidates to sit on the floor with the legs extended in front and the soles of the feet flat against a box. With palms facing downwards the candidate reached forward along the measuring line as far as possible. The longest distance reached was recorded. The maximum number of push-ups and heaves the participant could complete using correct technique, in time with a 2-s (push-ups) or 4-s (heaves) cadence, were then recorded. A seven-stage sit-up test was then performed. Candidates were required to complete one repetition of sit-up of progressively increasing difficulty [7]. The highest level successfully completed was recorded. To test candidate's agility, the time to complete a course of five cones spaced approximately 3-m apart in a zigzag pattern (90° angles) was recorded. A 20-m

shuttle run test was completed to estimate maximal aerobic power [6]. Candidates wore t-shirt, shorts and athletic shoes for these assessments. A 20-30 min rest break separated each of the assessments, and a 1.5 hour break for lunch was provided to candidates before the final two assessments of the SFET. A 5-km pack march was conducted on a flat grassed oval. Candidates were required to complete this assessment as fast as possible, without running or shuffling. Candidates wore standard combat uniform and boots, and carried 40 kg of external load in hip-webbing and a pack. The final test was a timed 400-m swim in a 50-m pool during which candidates wore their swim wear. It should be mentioned that a test of anaerobic power (yo-yo) was also performed during the SFET, however, due to missing data on candidate performances it has been excluded from the analysis presented.

At the commencement of the selection courses candidates were required to complete a barrier test consisting of a 3.2-km battle run and a 20-km march. The 3.2-km battle run requirement had candidates complete the distance within 16 min while dressed in webbing (7 kg) and carrying a weapon. The 20-km march requirement had candidates complete the distance in 3h15min dressed in pack and webbing (28 kg) and carrying a weapon. If candidates did not complete these barrier assessments within the required time period they were removed from the course. Barrier test data from CSTC candidates were collected to inform part A of this study.

Statistical Analysis

Differences in SFET and barrier assessments between comparison groups (pass/fail) were assessed by t-test. Multiple linear regression using a stepwise method of variable entry was conducted and the standardised beta coefficients are presented for the SFET

assessments contributing significantly to the models observed. Discriminant function analysis is a multivariate statistical technique designed to assess how well a set of continuous independent variables (in this case SFET assessments) predicts membership to a categorical grouping variable (pass/fail) [9]. This was used to investigate the potential for several of the SFET assessments to predict CSTC outcomes. The practical significance of the models was evaluated based on the number of correct and incorrect classifications made. Incorrect classifications should be minimised for the models to effectively screen candidates from Special Forces selection. Significance for statistical analysis was accepted at $p < 0.05$.

RESULTS

Development of the Standards (Part A)

A total of 39 candidates (37.5%) successfully completed the CSTC. Sixty-five candidates (62.5%) failed to complete the CSTC, of which 27 (26.0%) failed the 20-km march barrier assessment, 12 (11.5%) were removed for medical reasons, 9 (8.7%) withdrew at their own request, and 17 (16.3%) were withdrawn following a board of studies review (eg. failing skill based activities).

Barrier assessments

A performance range of 6 min separated the slowest (19.9 min) and fastest (13.9 min) candidates on the 3.2 km battle run (Table 1). On the 20-km march, the slowest (210 min) and fastest (166 min) spanned a performance range of 44 min (Table 1). A significant statistical model to predict 3.2-km battle run performance time was observed (adjusted $r^2 = 0.257$; $F_{4,96} = 9.649$, $p < 0.001$), with VO_{2max} (-0.314, $p = 0.001$), maximum number of push-ups (-0.231, $p = 0.009$), sit-up level (-0.199, $p = 0.024$), and

5-km march performance (0.209, $p=0.029$) as significant predictors. A statistically significant regression model was also observed for 20-km march performance time (adjusted $r^2=0.381$; $F_{3,76} = 14.412$, $p<0.001$). The SFET assessments significantly contributing to the model included 5-km march performance (0.403, $p<0.001$), vertical jump height (0.269, $p=0.004$), and maximal aerobic power (0.274, $p=0.005$). The standard error in estimating the performance time was 0.86 min and 8.1 min for the 3.2-km battle run and 20-km march respectively.

A significant model was found for predicting a pass or fail outcome on the 20-km march assessment (Wilks' Lambda = 0.811, Eigenvalue = 0.233, chi-square =19.61, $p<0.001$). SFET assessments significantly contributing to the model included 5-km march performance (-0.701, $p=0.004$), sit-up level (0.554, $p=0.02$), and maximal aerobic power (0.499, $p=0.04$). The model correctly classified 76% of candidates. There were 17 false positive classifications, where the candidates were predicted to pass but did not. Only 6 false negative classifications were made, where candidates were predicted to fail but in fact passed.

Selection Course Outcomes

Table 1 summarises the difference in SFET assessments between pass and fail groups on the CSTC. Candidates that passed the CSTC completed the 3.2-km battle run and 20-km march significantly quicker, and completed a greater number of push-ups. When the candidates who were specifically removed for failing the 20-km march assessment were excluded from this analysis, 20-km march performance remained significantly faster in passing candidates (Table 1). Furthermore, passing candidates

completed more push-ups, however, 3.2-km battle run times were similar between the pass and fail groups.

Discriminant function analysis to predict CSTC outcome was assessed firstly with only SFET assessments, and secondly with both SFET assessments and selection course barrier assessments. Two variations of these models were analysed, with and without those candidates who were removed for failing the 20-km march barrier assessment. When only SFET assessments were included as predictors, a significant model was observed (All candidates: Wilks' Lambda = 0.934, $p=0.009$; Excluding 20-km march fails: Wilks' Lambda = 0.946, $p=0.042$) with the push-up assessment highlighted as the only significant predictor of the CSTC outcome. However, these models were only able to correctly classify 66 – 68% of candidates, with between 14 (excluded 20-km march fails) to 28 (all candidates) false negative classifications. False positive classifications were low, with only 5 (all candidates) and 12 (excluding 20-km fails) resulting from these models.

When including the barrier assessments in the analysis, only the 20-km march performance significantly contributed to the prediction of success on the CSTC (all candidates: Wilks' Lambda = 0.811, $p<0.001$; Excluding 20-km march fails: Wilks' Lambda = 0.900, $p=0.007$). This model was able to correctly classify 60 – 65% of soldiers, with 9 (all candidates included in analysis) to 12 (analysis excluded those who failed the 20-km march) false negative classifications, and 19 (all candidates) and 16 (excluding 20-km march fails) false positive classifications.

The preceding analyses revealed that statistical modelling was unable to provide models for predicting success on CSTC with sufficiently high sensitivity and

specificity. However, the analysis did highlight the SFET assessments that were significantly associated with success on the 20-km march and CSTC, which included the 5-km march time, push-ups, sit-ups, and maximal aerobic power. Candidate performance on these assessments were analysed further to identify performance standards that, when applied in combination, provided greater sensitivity in reducing false negative predictions.

A manual analysis process of trialling a variety of performance standards for these assessments and observing how the false negative and false positive classifications were affected was undertaken. The criteria for choosing standards was firstly to maximise the identification of candidates who would fail CSTC (true negative), but also ensuring candidates capable of passing the selection course were not excluded (false negative). The best combination of standards on these assessments included completing the 5-km march in 45:30 min:s, achieving \geq level five on the sit-up test, and completing ≥ 66 push-ups. These standards were used in combination, such that, if a candidate passed 1, 2, or all 3 of these standards, they were predicted to successfully complete CSTC. Candidates would only be predicted to fail CSTC if they did not pass any of these performance levels. These standards were determined to be the most effective because they did not exclude any candidates who passed CSTC (zero false negatives) and correctly identified twenty candidates who failed (true negatives) (Figure 1).

Application of the Standards (Part B)

A total of 23 candidates (24%) successfully completed SAS-SC. Seventy four candidates (76%) failed to complete the SAS-SC, of which 21 (22%) failed a

component of the barrier assessments, 8 (8%) were removed for medical reasons, 36 (37%) withdrew at their own request, and 9 (9%) were withdrawn for failing skill based activities.

Figure 2 display's the percentage of candidates passing/failing SAS-SC categorised by the number of SFET standards they met (Part A). Of the thirteen candidates who failed to meet any of the SFET standards (predicted to fail SAS-SC) one actually passed the selection course, indicating a false negative classification by the proposed standards. A review of this candidates results revealed that the candidate notably failed the push-ups (40 reps) and sit-up (Level 4) standards, but failed the 5-km pack march by only eight seconds (45:38 min:s). As it is critical that false negative classifications are eliminated, the proposed 5-km march standard was adjusted by 15 s (to 45:45 min:s) to accommodate for this individual. These new standards were then re-applied to the outcomes of both the CSTC (Part A) and SAS-SC (Part B) cohorts to determine its affect on false negative and false positive classifications. The adjusted standards correctly predicted all passing candidates on both the CSTC and SAS-SC (Table 2). In addition, 19 and 13 candidates were correctly predicted to fail CSTC and SAS-SC respectively.

DISCUSSION

The present investigation identified maximal aerobic power, maximum number of push-ups, sit-up level, 5-km march performance, and vertical jump height to be associated with performance of the 3.2-km battle run and 20-km march barrier assessments. In addition, the maximum number of push-ups and 20-km march performance were identified as contributors to statistical models for predicting

success on the CSTC. Although the statistical models did not provide sufficient sensitivity and specificity in predicting selection course outcomes, the analysis revealed the SFET assessments contributing to success. Through a process of manual analysis in a second cohort, a combination of standards was developed to firstly, ensure no candidates capable of passing the selection courses would be prevented from attempting it, and secondly, to maximise the identification of candidates who were likely to fail the selection course. The final standards included completing the 5-km pack march in $\leq 45:45$ min:s, achieving \geq level five on the sit-up test, and completing ≥ 66 push-ups to a 2-s cadence.

Statistical Modelling

The 3.2-km battle run and 20-km march barrier assessments were performed in the first few days of the selection courses. Candidates failing to meet minimum performance standards were removed from the course on the grounds of insufficient physical capability. Since the barrier assessments were performed at the outset of the selection course, candidates commencing the course are expected to possess the required physical capability to pass. Although statistically significant models were found, only 25% of the variance in the 3.2-km battle run performance time was accounted for by the model. Predicting 20-km march time had greater reliability, with the model accounting for 38% of the variance in march time. These findings show these measures of physical fitness are important contributing factors in determining performance on the barrier assessments, but that other factors contributed to $>50\%$ of 3.2 km battle run and 20-km march performance.

The sensitivity and specificity of SFET assessments in predicting barrier assessment and selection course outcomes are important for the practical application of the models. Although the classification models were statistically significant, several incorrect classifications resulted from its application. Importantly, many of the incorrect classifications were false negative, predicting candidates to fail when in fact they went on to pass the CSTC. It is imperative that false negative classifications are eliminated so that potentially valuable Special Forces operators are not lost. As such, the current statistical models did not offer sufficient sensitivity to reliably screen applicants onto Special Forces selection courses.

Several reasons are proposed for the low sensitivity and specificity of the statistical models to predict selection course outcome. Firstly, the sample of candidates in this study was of a relatively similar and high level of physical capability. Within the homogenous nature of this cohort there may not have been enough candidates of low physical capability to draw out the importance of the SFET assessments in predicting success. This is likely to be a sustained issue given Special Forces applicants will generally have a similarly high level of physical capability [10]. However, the data does highlight that when physical capability attributes are similar, other factors must play a significant role in determining success on Special Forces selection courses. These other factors are likely linked with the non-physical reasons for being withdrawn from selection courses and include withdrawal at own request, medical removal due to injury, and unsatisfactory skill based competency. The non-physical reasons for withdrawal at the candidate's own request may lie in the candidate's cognitive and psychological state, including their mental hardiness [11] and self-confidence [10]. While some instances of medical withdrawal may be unpredictable,

structural weaknesses or muscular imbalances in a candidate's musculoskeletal profile may predispose them to injury [12]. Also, non-physical skill based attributes such as reasoning, numeracy, and mechanical comprehension have previously been associated with the chance of selection to the Royal Marines [5].

Finally, the low strength of the statistical models developed in this study may lie in the SFET assessments themselves. The SFET assessments are generalised fitness assessments and may not be reflective of the physical demands actually encountered during the selection courses. For example, several of the assessments on the SFET, including heaves, flexibility, and agility, were not found to significantly contribute to any of the models developed. As such their inclusion in the SFET may need to be reconsidered. The inclusion of more military specific physical capability assessments in the SFET may show greater sensitivity in predicting success.

Standards Development

Even though the statistical analysis did not provide models of sufficient sensitivity and specificity to be implemented, the analysis did reveal the SFET assessments associated with successful course completion. These included the 5-km march assessment, push-ups, sit-up level, and maximal aerobic power. Assessments of marching with load carriage are highly relevant to military operations and are a key component of the Special Forces selection courses. As such, it is not surprising to find the 5-km march to be a significant predictor of course success. The sit-up level attained is reflective of trunk strength which is important for the safe and effective completion of many functional tasks involving whole body movement. Military tasks that require muscular strength or endurance for upper body pushing movements

(push-ups) may include crawling, pushing, and rising from a prone firing position. In addition, it may be that push-ups are used as a fatigue enhancing tool or for disciplinary training throughout the selection course. On this basis, the ability to repeatedly perform push-ups may be integral in distinguishing those who can successfully complete the course. These findings are in agreement with other research showing assessments of these physical capabilities to be related to simulated battlefield performance [13].

The standards developed in the present study include completing the 5-km pack march in $\leq 45:45$ min:s, achieving \geq level five on the sit-up test, and completing ≥ 66 push-ups. These standards should be used in combination, such that, if a candidate passes one, two, or all three, they would be predicted to pass the selection course. Candidates would only be predicted to fail the selection course if they did not pass any of these performance levels. The present study evaluated the cross-course applicability of these standards through evaluating two independent cohorts of candidates where zero false negative classifications were made (Table 2). As such these standards did not exclude any candidates from commencing the selection courses that were able to successfully complete it. Consequently, these standards ensure no loss of potential Special Forces operators. In addition, a small proportion of candidates were correctly identified as likely to fail the selection courses (true negative) (Table 2). Identifying those candidates that are least likely to pass the course is beneficial for two main reasons. Firstly, it is foreseeable that candidates with insufficient physical capability are not only more likely to fail, but may also be at greater risk of injury when undertaking the course [1]. Preventing these candidates from commencing the course may help to reduce injury rates and increase course

completion rates. Secondly, there would be a lower financial and logistical burden of conducting the selection courses, as fewer soldiers would be commencing the course and the ones commencing are more likely to succeed.

Another advantage of setting standards for SFET assessments is the opportunity to become proactive in the recruitment process and to mentor potential candidates towards success. A mentorship program provides Special Forces with several opportunities including the capture of potential future candidates, recapture of unsuccessful candidates who have demonstrated sufficient potential to warrant reapplication, and increasing the pool of candidates with a high chance of future course completion.

CONCLUSION

The present study revealed the SFET assessments associated with performance on Australian Army Special Forces selection courses. Performance time on the 3.2-km battle run and 20-km march barrier assessments were improved in candidates who had a greater maximal aerobic power, could complete more push-ups, attain a higher sit-up level, complete the 5-km march quicker, and jump higher. Performance on the 5-km march, sit-up level attained, and maximal aerobic power were also associated with a greater chance of passing the 20-km march barrier assessment. Although statistical modelling was unable to provide the required level of sensitivity in predicting selection course outcomes (pass/fail), a manual analysis approach to determine a combination of SFET standards that, when applied in combination, was successful at retaining all candidates capable of passing the selection courses was developed. These standards include completing the 5-km pack march in $\leq 45:45$ min:s, achieving \geq level

five on the sit-up test, and completing ≥ 66 push-ups. The implementation of these standards will benefit the Special Forces selection process by increasing course completion rates, reducing injury rates, reducing financial and logistics burdens of selection course coordination, and enhancing recruitment opportunities.

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Table 1: SFET performance (mean \pm SD) across the CSTC Outcome groups.

	Pass	Fail (all candidates)	Fail (excluding 20-km march fails)
n	39	65	38
SFET Assessments			
Maximal Aerobic Power (mL \cdot kg ⁻¹ min ⁻¹)	55.1 \pm 3.3	54.2 \pm 2.8	54.8 \pm 3.3
5-km march (min)	45.2 \pm 2.4	45.9 \pm 2.2	45.2 \pm 1.6
Push-ups (repetitions)	69 \pm12	63 \pm12 *	63 \pm14*
Sit-ups (level)	4.6 \pm 1.3	4.2 \pm 1.4	4.4 \pm 1.3
Heaves (repetitions)	12 \pm 2	12 \pm 2	12 \pm 2
Agility (s)	8.1 \pm 0.6	8.0 \pm 0.7	7.9 \pm 0.8
Swim (min)	8.6 \pm 1.2	8.9 \pm 1.2	8.9 \pm 1.2
Flexibility (cm)	31.2 \pm 5.9	30.3 \pm 5.6	30.5 \pm 6.0
Jump Height (cm)	55.7 \pm 7.1	55.6 \pm 6.8	55.9 \pm 6.6
Barrier Assessments			
3.2-km battle run (min)	15.0 \pm0.7	15.5 \pm1.1 *	15.1 \pm 0.7
20-km march (min)	182.9 \pm9.0	192.0 \pm9.6 *	187.6 \pm7.3*

* Significantly different from the pass group, $p < 0.05$.

Table 2: Actual and predicted Selection Course outcomes from the adjusted SFET standards.

	Actual Course Outcome		Predicted Course Cohort Following Implementation Of adjusted SFET Standards			
	PASS	FAIL	True Positive	True Negative	False Positive	False Negative
SAS-SC	21 (23%)	71 (77%)	21 (23%)	13 (14%)	58 (63%)	0
CSTC	39 (38%)	65 (63%)	39 (37%)	19 (18%)	46 (44%)	0

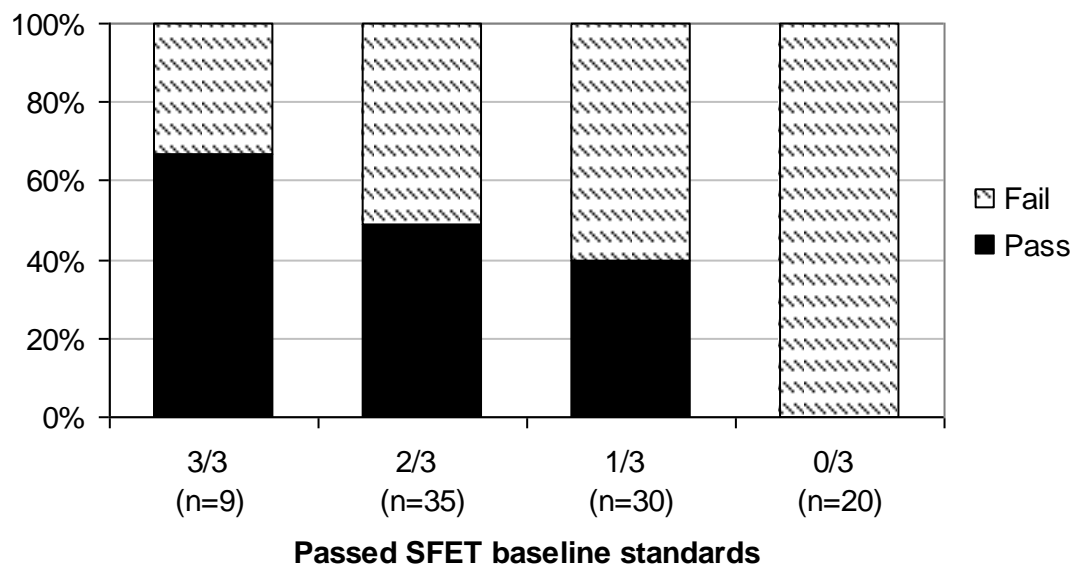


Figure 1: Percentage of pass/fail CSTC outcomes for candidates grouped according to the number of SFET standards passed.

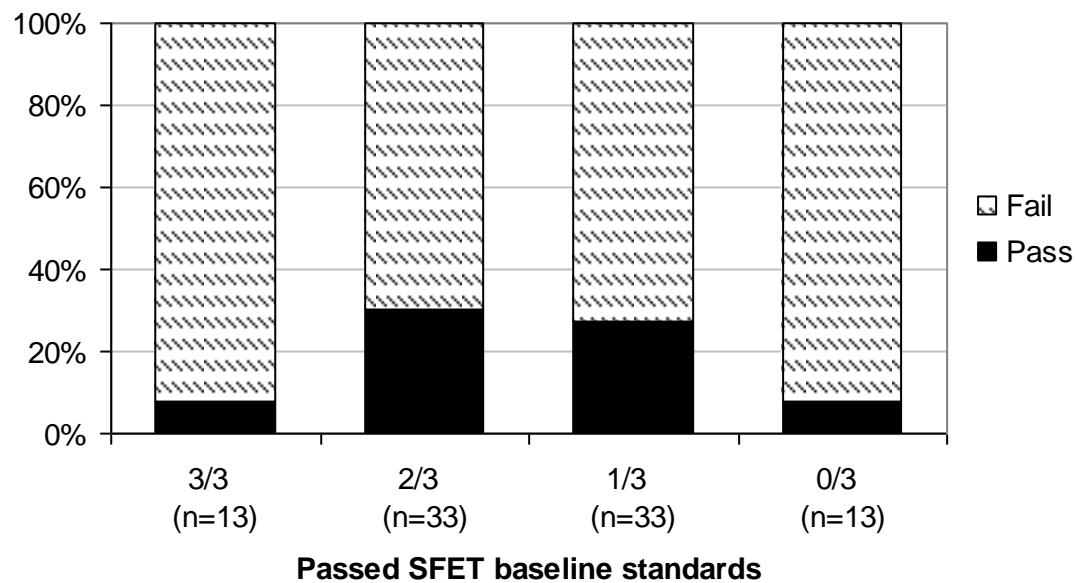


Figure 2: Percentage of pass/fail SAS-SC outcomes for candidates grouped according to the number of SFET standards passed (part A).